

2000

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Xing, Z.; Peng, X.; and Shu, P., "Development and Application of a Software Package for the Design of Twin Screw Compressors" (2000). *International Compressor Engineering Conference*. Paper 1492.
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DEVELOPMENT AND APPLICATION OF A SOFTWARE PACKAGE FOR THE DESIGN OF TWIN SCREW COMPRESSORS

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ABSTRACT

The development and application of a software package for the design of twin screw compressors is presented in this paper. The package can be used to calculate the rotor profile, geometrical characteristics, thermodynamic performance, forces on rotor, rotor deflection and cutter shape. A user-friendly interface and some powerful post-processing programs are also included in the package. The application of the package is demonstrated by the successful development of several types of new compressor and the generation of various new rotor profiles. The package has also been used to improve the performance of a number of existing machines, and very satisfactory results are obtained. It is also shown that a modified version of the software package can be provided easily to calculate the patent profiles of specific companies.

INTRODUCTION

Twin screw compressor is widely used as air, refrigeration and process compressor because of its advantages such as compact construction, reliable operation and free of vibration^[1]. During the past years, most of the companies which manufacture twin screw compressor have developed some computer programs based on the working process simulation, and applied them in the development of new rotor profiles and in the design of new series of twin screw compressor ^[2,3,4,5]. The program can be also integrated into a software package to make it be accessed by more designers and engineers^[6].

Based on systematic theoretical modeling and extensive experimental investigation on the working process, a software package for the design of twin screw compressors called SCCAD has been developed. A number of new rotor profiles have been generated and several types of new twin screw compressor are developed by making use of this package. The package has also been used to improve the performance of some existing compressors.

MAIN PROGRAMS OF THE SOFTWARE PACKAGE

The computer programs in the software package SCCAD were first developed several years ago^[7,8,9], and have been updating in recent years^[10]. Its most recent version is SCCAD 3.0 for Windows. The SCCAD package includes six main programs, i.e. profile generation, geometrical characteristics calculation, performance simulation, rotor forces analysis, rotor deflection calculation and cutter shape calculation. Besides the six main programs, a lot of efforts are also made on developing a user-friendly interface and powerful post-processing programs.

Profile Generation

The rotor profile in SCCAD is generated following the procedures described below: Firstly, some curves are defined on one of the rotor as various segments of the profile. Then, The curves conjugating with these curves on another rotor is obtained according to the meshing gear theory. Six types of different profile are integrated in the program "Profile". The input data file of this program defines the profile parameters such as rotor lobe combination, center distance between the rotors, radius of the male rotor crest, addendum of the female rotor, etc. For each type, the profile can be generated according the various profile parameters defined by the user.

Geometrical Characteristics Calculation

Geometrical characteristics include contact line length, blow hole area, profile coefficient, suction and discharge port areas, and the variation of cavity volume, etc. The calculation of these characteristics is essential to simulate the working process and evaluate a rotor profile. Based on the result of "Profile", program "Geometry" calculates the characteristics mentioned above by further considering rotor parameters like wrap angle and rotor length.

Performance Simulation

By making use of this program, the working process characteristics like pressure, temperature and mass variation in the twin screw compressor can be analyzed by solving a group of equations governing the suction, compression and discharge processes. Moreover, some performance parameters can also be calculated from these process characteristics such as flow rate and power consumption of the compressor. Several types of gas are included in this program, and this enables the program can be used for compressors with different working media such as air, gas, and various refrigerants.

Forces Analysis

Based on the results of program "Performance" and "Geometry", the "Force" program calculates the forces and torque acting on the rotor. The contact region and non-contact region are dealt with differently according to the projection of contact line on different coordinate planes. The bearing loads are also calculated according to the rotor geometrical dimensions.

Rotor Deflection Calculation

The "Deflection" program calculates the rotor deflection by taking account of forces acting on the rotor and heat expansion of the rotor. The result of this program is very important to evaluate a certain profile and modify the cutter shape.

Cutter Shape Calculation

According to the results of "Profile", theoretical cutter shape is first calculated in this program. Then, the shape is modified by considering the deflection of the rotor due to heat expansion and force. Finally, the practical cutter shape is obtained by further modifying the shape with the consideration of clearance.

FLOW CHART OF THE SOFTWARE PACKAGE

Fig.1 shows the flow chart of the software package SCCAD. The programs in SCCAD are independent relatively, so it is easy to be updated according to the latest research achievements.

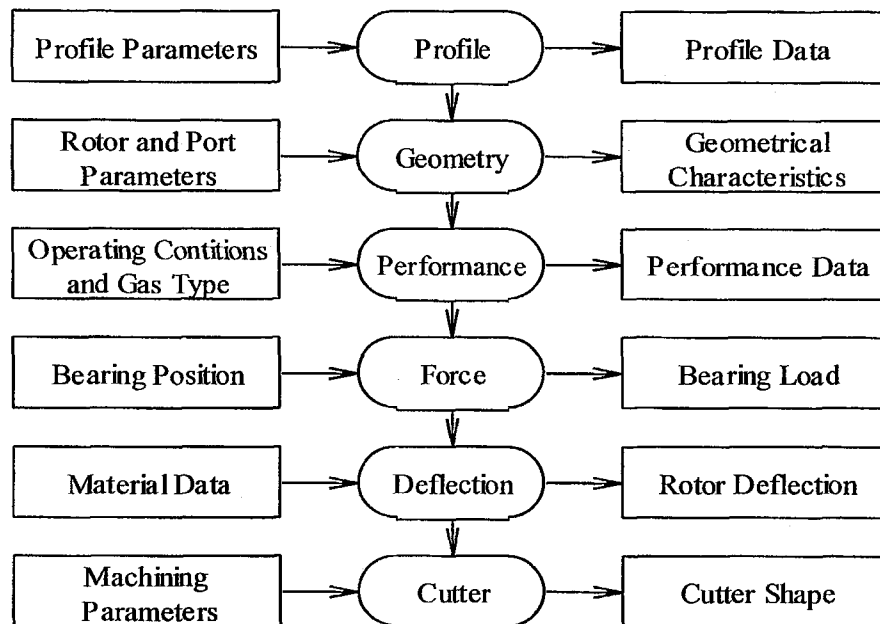


Fig.1 Flow chart of the software package SCCAD

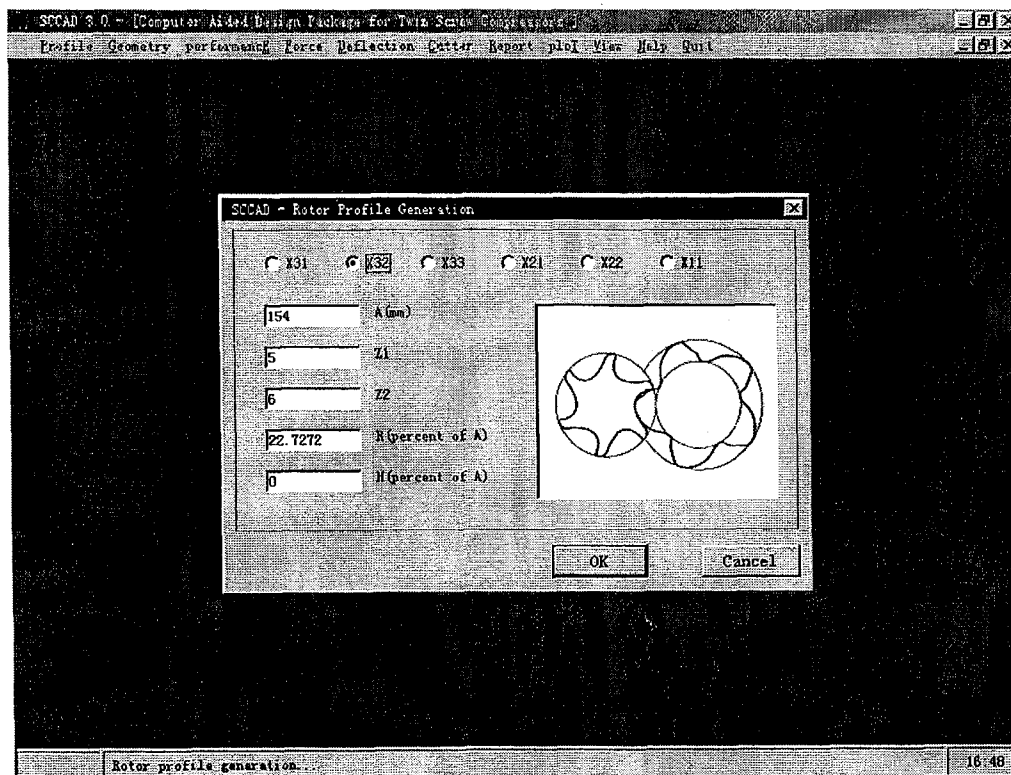


Fig.2 Main interface of SCCAD 3.0 and its sub-interface for inputting rotor profile parameters

INTERFACE OF THE SOFTWARE PACKAGE

In order to enable more design engineers to make use of the computer programs, a user-friendly interface based on the Windows operating system is developed. Moreover, some powerful post-processing programs are also integrated into the software package to report the calculated data, plot the graphic curves and view the animation of working process. Fig.2 shows the main interface of SCCAD 3.0 and one of its sub-interfaces for inputting rotor profile parameters. Fig. 3 shows its another sub-interface for plotting the important graphic curves.

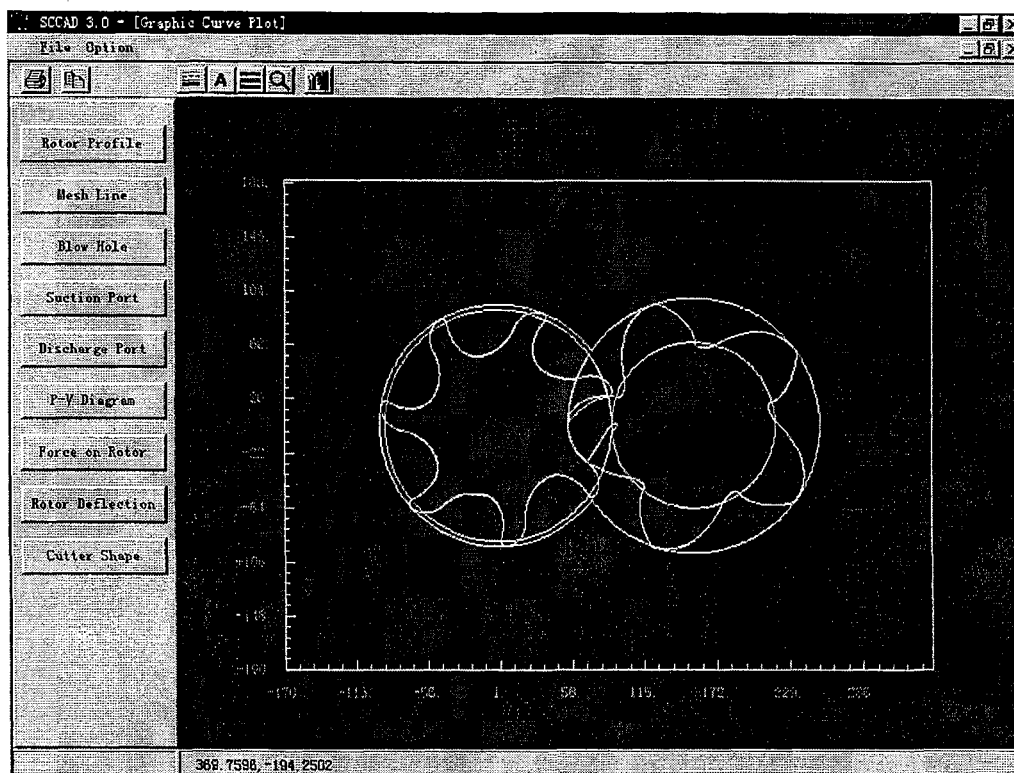


Fig. 3 Sub-interface of SCCAD 3.0 for plotting the important graphic curves

APPLICATION OF THE SOFTWARE PACKAGE

Design of New Compressor

The calculation work in a twin screw compressor design can be completed in a few hours with the help of SCCAD, while it usually needs a few weeks with the conventional method. Moreover, the design parameters can be optimized according to the specific applications by using numerical test on computer. These design parameters include construction and operating parameters such as the ratio of rotor length to its diameter, wrap angle and rotor tip speed, suction and discharge ports position, etc. The SCCAD package has been used to design the following new twin screw compressors: a series of stationary oil-flooded air compressor with 5 models; a series of portable oil-flooded air compressor with 6 models; a series of open-type refrigeration compressor with 7 models; a series of semi-hermetic refrigeration compressor with 5 models; a type of oil-free nitrogen compressor and a type of oil-free chlorine compressor.

Most of the new twin screw compressors designed with SCCAD have been developed and marketed successfully. Fig.4 shows the specific power consumption variation of QLG-3/10, a portable oil-flooded air compressor^[11]. It can be seen that the specific power consumption is kept nearly constant under various speeds. This means the twin screw compressor can maintain a satisfactory performance under different speeds such as controlled by an inverter. It also indicates that a whole compressor series can be formed by only a few types of rotor.

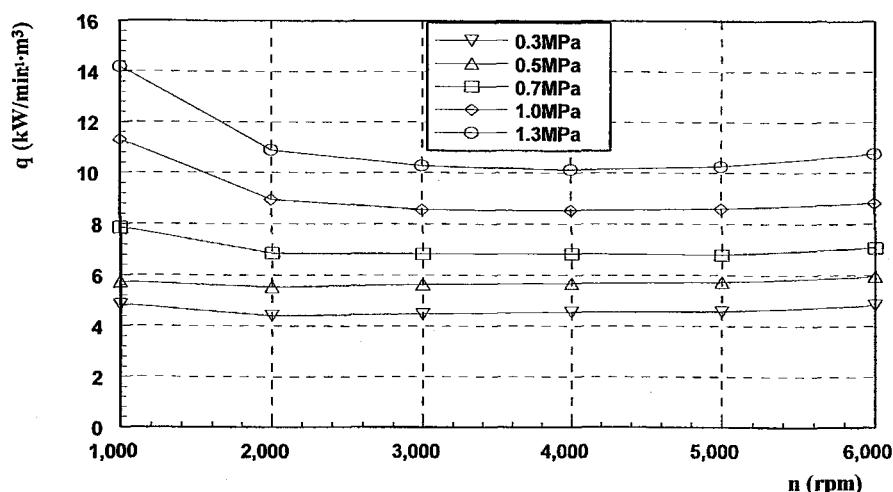


Fig.4 Specific power consumption of QLG-3/10 under various speed and discharge pressure

The procedures of using SCCAD in the design of a twin screw compressor is illustrated in the design of model GY-17/7^[12]. It is shown that the SCCAD package can be used in all important aspects such as generating rotor profile, selecting position of discharge and suction ports, calculating bearing loads and cutter shape, etc.

Generation of New Rotor Profile

The generation of rotor profile is the most important part in a twin screw compressor design since the profile can affect the compressor performance and manufacture cost significantly. Making use of the program "Geometry" in the package, the profile parameters can be selected preliminary. Then, the parameters can be optimized based on the program "Performance" and "Force". Finally, the parameters are checked by "Deflection" program to make sure deflections of each rotor are acceptable. According to the steps mentioned above, a number of new rotor profiles has been generated and adopted in various types of twin screw compressor^[13].

Fig.5 shows a new rotor profile generated for a series of small air compressor with the flow rate of 0.5-1.8 m^3/min . It is a single-sided profile and all its segments are circular arcs. The lobe combination of the male and the female rotor is 4+5, so it has the advantages of short contact line and large profile coefficient.

Fig.6 shows a new rotor profile generated for a series of small refrigeration compressor with the power consumption of 10-20kW. It is a double-sided profile and has ellipse arc as one of its segments. The lobe combination is 5+7, so the stiffness of the female rotor is enhanced to make sure the deflection of the rotor is still acceptable even operating at 50°C high condensing

temperature.

Fig.7 shows a new rotor profile generated for a series oil-free compressor with low discharge pressure. It is a double-sided profile and all its segments are circular arcs. The lobe combination is 3+4 in order to obtain a higher profile coefficient.

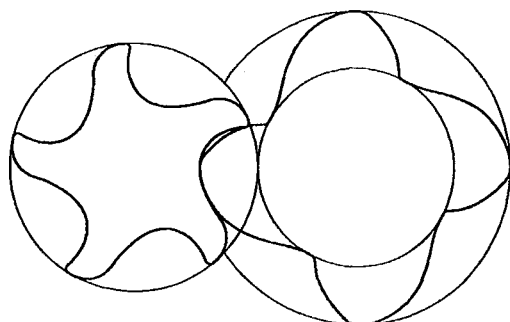


Fig.5 New rotor profile for small air compressor

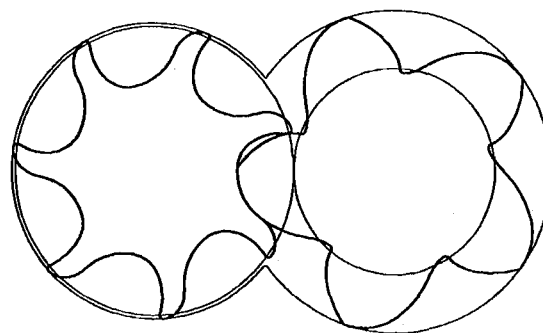


Fig6 New rotor profile for small refrigeration compressor

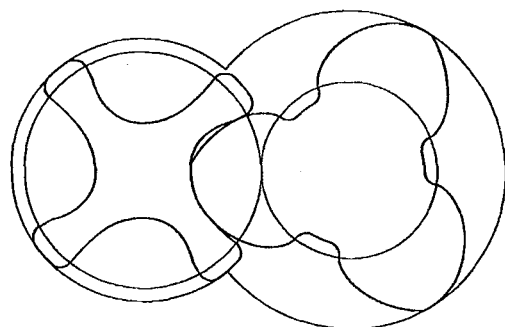


Fig.7 New rotor profile for oil-free compressor

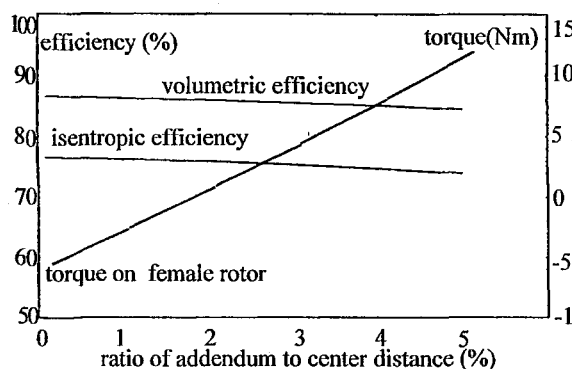


Fig. 8 Effect of female rotor addendum on performance

Taking the selection of female rotor addendum as an example of parameter optimization. Fig. 8 shows the effect of this profile parameter on compressor performance. It can be seen that both the volumetric and the isentropic efficiency decrease with the increase of this parameter. So it seems a smaller value of this parameter should be selected from the aspect of thermodynamic performance. But it can also be seen both the direction and magnitude of the torque on the female rotor developed by the gas pressure are also affected significantly by this parameter. Here minus torque indicates it is a driving torque. When this torque is designed according to the friction torque on the same rotor, the so-called “zero” driven-torque can be achieved. So the contact force and stress between the rotors are also very small, and lubrication between the rotors can be easily achieved with less oil or other fluids like water and refrigerant. It should also be pointed out that the torque on the female rotor must be checked under all the possible operating conditions to make sure its direction does not change during operation. Otherwise, abnormal noise and vibration could be generated due to the chatter of the female rotor.

Performance Improvement of Existing Compressor

The performance of most old series of twin screw compressor is not very well because of the limitation in design techniques during the early days. Their performance can usually be improved with the help of the latest design software such as SCCAD and other CFD codes.

The software package SCCAD has been used to improved an existing series of open-type refrigeration compressor. After theoretical analysis of the compressors with SCCAD, together with the experimental measurement of their performance, p-V diagram and pressure pulsation, some design parameters are optimized. As the result, 5-7% increase of isentropic efficiency and 2-5 dB(A) decrease of noise have been achieved. It is also worth to be pointed out that the optimization is carried out by taking account of the original parameters of the existing compressors. For example, during the profile optimization the center distance between the rotors is kept the same and the diameters of the rotor only change a little. Then during the manufacturing of the new compressor, the casting model, clamping fixture and machining tool of the old compressor can still be used. So the capital investment for manufacturing the new machine is saved significantly and the new compressor can also be marketed in a very short period.

Study of System with Twin Screw Compressor

The software package SCCAD can not only be used in the design and study of twin screw compressor itself, but also in the study of system with twin screw compressor in it. For example, the performance of refrigeration system with twin screw compressor and superfeed circuit can only be analyzed in detail after fully understanding the behavior of twin screw compressor in the system^[14].

Modified Version of SCCAD for Specific Company

The software package SCCAD has been licensed to 6 leading manufactures of twin screw compressor. Besides the standard version, the modified version of SCCAD has also been provided to some users with their own patent profile integrated into the package. All the need is only to modify the "Profile" program in the package or to provide the profile data files according to the requirement of SCCAD. Then All the left programs in SCCAD can be used without any modification.

CONCLUSIONS

Based on systematic theoretical modeling and extensive experimental investigation on the working process, a software package for the design of twin screw compressors called SCCAD has been developed. It is demonstrated that the design work of twin screw compressor can be done quickly and precisely with the help of this package. A number of new rotor profiles have been generated and several new twin screw compressors have been developed by making use of this package. The package can also been used to improve the performance of existing compressor and do research about various systems using twin screw compressor.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to the Chinese State Education Ministry for the financial support in making this research possible.

REFERENCES

1. Xing Ziwen, "Screw Compressors: Theory, Design and Application", China Machine Press, Beijing, 2000(In Chinese)
2. Sangfors B., "Computer Simulation of the Oil Injected Twin Screw Compressor", Proceedings of the International Compressor Engineering Conference at Purdue, USA, 1984
3. Singh P.J. and Bowman J.L., "Effect of Design Parameters on Oil-flooded Screw Compressor Performance", Proceedings of the International Compressor Engineering Conference at Purdue, USA, 1986
4. Fujiwara M., Kasuya K. and Osada Y., "A New Design Method for Oil-Injected Screw Compressors and Its Application", Hitachi Review, Vol.36(1987), №.3
5. Fleming J.S., Tang Y. and Anderson H., "Optimization Techniques Applied to the Design of a Refrigeration Twin Screw Compressor", Proceedings of the International Compressor Engineering Conference at Purdue, USA, 1994
6. Stosic N. and Hanjalic K., "Development and Optimization of Screw Engine Rotor Pairs on the Basis of Computer Modeling", Proceedings of the International Compressor Engineering Conference at Purdue, USA, 1994
7. Peng N.X., Xing Z.W., Deng D.G. and Shu P.C., "New Rotor Profile and its Performance Prediction of Screw Compressor", Proceedings of the International Compressor Engineering Conference at Purdue, USA, 1990
8. Xing Z.W., Deng D.G. and Shu P.C., "A CAD System for Twin-Screw Compressors", Proceedings of the International Compressor Engineering Conference at Purdue, USA, 1992
9. Xing Z.W., Deng D.G. and Shu P.C., "A New Design Method for Twin Screw Compressors and Its Application", Journal of Xi'an Jiaotong University, Vol.27(1993), №.4 (In Chinese)
10. Xing Z.W., Peng X.Y. and Shu P.C., "Development of a CAD System for Screw Compressors", Fluid Machinery, 1997, №.3, (In Chinese)
11. Xing Z.W., Deng D.G. and Shu P.C., "Development of a Portable Oil-flooded Twin Screw Air Compressor", Fluid Machinery, 1992, №.3, (In Chinese)
12. Jiang R.F., Xing Z.W. and Shu P.C., "Optimum Design of a Portable Twin Screw Air Compressor", Proceedings of the Second International Compressor Technique Conference, Chengdu, China, 1997
13. Xing Z.W., Peng X.Y. and Shu P.C., "Study and Design of New Rotor Profile for Twin Screw Compressors", Compressor Technique, 1997, №.1, (In Chinese)
14. Fleming J.S., Tang Y., Xing Z.W. and Cook G., "The Use of Superfeed in a Refrigeration Plant With a Twin Screw Compressor: an Optimization Technique for Plant Design", Proceedings of the IIR XIXth Congress on Refrigeration, The Hague, 1995